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*A Contribution to the Geology of the Lower Amazonas.**

BY ORVILLE A. DERBY, M. S.

(*Read before the American Philosophical Society, Feb. 21, 1879.*)

In the following sketch of the geology of the region of the Lower Amazonas I have attempted to give a résumé of the most important results of the studies made by, and under the direction of, the late Prof. Ch. Fred. Hartt, in whom Science mourns the loss of one of its brightest ornaments in North America, and of its chief and ablest expounder in the southern continent. It is, for the most part, condensed from an extensive report, prepared by Prof. Hartt as chief of the Geological Commission of the Empire of Brazil, the publication of which has been delayed, in consequence of the financial condition of the Empire and of the untimely death of the chief of the Commission.

The history of the explorations on which this sketch is based is briefly as follows: In 1870, Prof. Hartt, with a party of students, visited the Amazonas, ascending the Tocantins and the Tapajos to among their lower rapids, and examining the high lands of the vicinity of Santarem, Monte Alegre and Ereré. In the following year he returned, accompanied by myself, re-examined the Ereré and Tapajos regions and explored the table-topped mountains between Prainha and Monte Alegre, sending me, in the meanwhile, to Obydos and afterwards to the island of Marajó. These explorations gave rise to a number of special papers, published in the American scientific journals. On assuming direction of the Brazilian Geological Survey, Prof. Hartt engaged Mr. Herbert H. Smith, a member of the party of 1870, who was then on the Amazonas, to continue the geological exploration, and he afterwards sent me, with Dr. Francisco José de Freitas, to the same region. Together with these two gentlemen I re-examined the Ereré region, and ascended the Maecurú (Gurupatuba of the maps), as far as the fall called Pancada Grande. After this exploration, Mr. Smith continued the examination, which he had already begun, of the

*A Portuguese version of this report is also being published in the *Archivos do Museu Nacional* of Rio de Janeiro, Vol. II, 1878.

region about Alenguer, ascended the river Curuá de Alenguer as far as the Bem-fica fall, and afterwards revisited the lower Tapajos. Dr. Freitas and myself ascended the Trombetas and I afterwards revisited Marajó. The Devonian fossils have been studied by Mr. Richard Rathbun, while I have myself determined those of the Silurian and Carboniferous.

Having been intimately associated with Prof. Hartt in all the Amazonian work, I can claim but little originality in the conclusions drawn from the observations and presented in this article, the most of them having been presented by my illustrious teacher in his various publications, or brought out in our discussions on the subject, in such a way that it is now impossible to determine the authorship of each idea. The work of the last explorations by Messrs. Smith, Freitas and myself, in which Prof. Hartt, had no part, was mainly the determination of the character and age of the Ereré uplift, and of the extension and relations of the various Palæozoic deposits on the northern side of the Amazonas. It is proper to state that in regard to the Cretaceous age of the Ereré sandstone and the date of the elevation of the anticlinal, Prof. Hartt reserved his opinion for a more careful examination of the evidence that I had to present on that point, than he was ever able to make. I am confident, however, that if he had made such an examination, I should have been able to convince him of the accuracy of my observations and conclusions.

The river known to geographers by the name Amazonas has, like many other rivers, various names which are applied by the inhabitants along its banks to different parts of its course. These popular designations of Amazonas, or Baixo (Lower) Amazonas, Solimões and Marañon, mark approximately three sections of the valley, which are very distinct in physical characteristics and have very different geological histories. They may, therefore, be advantageously retained to designate the lower, middle and upper portion of the great river.

The differences in these three sections are due to the relations of the valley with the component parts of the South American continent; so that in order to understand the structure of the valley, we must bear in mind the general features, long since recognized, of that continent. This is composed of three distinct mountainous regions, more or less united by elevated plains, in which are excavated the great depressions occupied by the fluvial systems of the Orinoco, Amazonas and Rio de la Plata. The Andes form a long, narrow strip of great elevation, along the western coast, and the mountains of Brazil and of Guiana, considerably less elevated than the Andes, occupy extensive areas in the eastern and northern portions of the continent. The space between these three elevated regions or nuclei of the continent is occupied by vast elevated plains, generally less than three thousand feet high, except in a narrow strip between the highlands of Brazil and Guiana, in which the continuity of the plains is entirely interrupted by the depressed valley of the Amazonas. It is also to be noted that between the Andes and the two elevated regions of the eastern part of the continent, the continuity of the plateaux is almost de-

stroyed by the great cuts made by the Rios Paraguay and Madeira in the south, and the Rios Negro and Orinoco in the north, and only a comparatively slight continental depression would be required to entirely separate these regions. In fact, the region of Guiana may be considered an island, in consequence of the existence of that geographical phenomenon, the Cassiquiarí, uniting the Orinoco and Rio Negro.

The Amazonas, unlike the Orinoco and the La Plata in this respect, has relations with all three of the mountainous regions above indicated. The upper part, or Marañon, belongs exclusively to the Andes; the middle, or Solimões portion, is in the region intermediate between the Andes and the highlands of Brazil and of Guiana; and the Lower Amazonas, from the mouth of the Rio Negro to the sea, is between these two last masses of highlands.

From a purely geographical point of view, the Lower Amazonas and the Solimões might be united in a single section, because the differences between these two portions are, at present, much less than those between the Marañon and the rest of the great stream. Taking into consideration, however, the geological structure, and especially the conditions which geology shows to have existed in former times, it will be seen, as I hope to prove, that this division of the valley into three sections is a natural one.

An examination of the hydrography of the Amazonian basin, taken as a whole, reveals much more noticeable differences in the three portions than are seen in the valley properly so called. The Marañon and its great southern tributaries in the Andean region, the Huallaga and the Ucayale, descend from great elevations in the cordilheiras, and flow northerly in the general direction of the trend of the mountains, until, escaping from them, the Marañon takes an easterly direction, in which it presents a notable contrast with the Ucayale which, although it has descended to a comparatively low level, a long distance above its mouth, still continues to flow in a northerly direction, as if it were forced for some reason, to follow the margin of the mountainous region. The northern tributaries of the Marañon, including the Napo which empties nearly opposite the mouth of the Ucayale, descend from the Andes of Ecuador in a south-easterly direction, directed by the slope of the mountains. The area drained by the Marañon and its tributaries is very long in the direction north-south, but very narrow in the direction east-west.

In the Solimões region, on the contrary, the region drained on the north is rectangular in shape, the longest axis of the rectangle extending east-west, parallel with the river, and the tributaries in this region, including the Rio Negro, flow in valleys of slight elevation in an easterly direction, subparallel with the Solimões, as if they were crowded down towards the south, and directed in their courses by a line of highlands, uniting the mountains of Guiana with the Andes. The southern area, drained by the Solimões and included between the Ucayale, the Madeira, and the eastern prolongation of the Andes in Bolivia, is of triangular shape. The tributaries in this area rise in the plateau east of the Andes, at moderate eleva-

tions (the source of the Purús is according to Chandless at an elevation of only 1,088 feet above the level of the sea), and, as Chandless has already pointed out, flow in their upper courses in a general easterly direction, as if directed by an imperceptible slope from the Andes.

In the Lower Amazonas region, the mountains of Guiana are comparatively near to the river, and, in consequence, the northern tributaries are small and flow directly towards the main river, with a slight deflection towards the east. On the southern side, on the contrary, the great plateau of central Brazil extends from near the Amazonas to the headwaters of the Paraguay and the mountains of Goyaz. The great tributaries, Tapajos, Xingú and Tocantins, traverse this plateau in a northerly direction, and descend to the level of the Amazonas by a steep incline that commences a short distance above their mouths. I have purposely omitted to mention the Madeira, because this river is related to all three of the sections of the basin. One of its tributaries, the Guaporé, rises in the highest part of the central plateau of Brazil, and appears to flow along a margin of that plateau (the so-called Cordilheira de Parecis), until it joins the Mamoré which, like the Beni and Madre de Deus, descends from the high Andes of Bolivia, circling round the great eastern projection of the Andes, in the district of Santa Cruz de la Sierra. The lower Madeira, which forms the division between the regions of the Solimões and the lower Amazonas, flows northeasterly, subparallel with the great features of eastern Brazil, viz: the mountain chains of the coast and of Minas Geraes, and the valleys of the upper São Francisco and upper Paraná. Farther on I shall have to speak of the significance of this fact.

Let us now consider in greater detail, the physical and geological features of the Lower Amazonas region, the immediate subject of this article. What most impresses the traveler on the Amazonas, after the enormous extension, width and volume of the river, the labyrinth of its side channels and the richness of its flora, is the great extent of the *varzea* or flood-plain that, monotonous as the sea, accompanies the river in a broad belt on each side, from the mouth to the foot of the Andes. Being generally well wooded, the forest gives this flood-plain a false appearance of dry land, and the traveler is very liable to be deceived regarding its true character and extent. To form a true estimate of its importance, it is necessary to ascend one of the few eminences which occur along the margin of the river, as those of Monte Alegre, Santarem and Obydos. From these elevations there is seen a great marshy plain, almost on a level with the river, diversified with lakes and island-like groups of trees, and intersected by numerous anastomosing lateral canals, *furos* or *paraná-merins*, which plain extends for many miles to the highlands of the opposite side, visible in the distant horizon. In this vast plain, the river, great as it is, appears a narrow ribbon of water, almost lost in the immensity of its ancient bed, for the *varzea* can only be considered as a portion, which has been filled up, of the original bed of the river, or, rather, of the estuary which preceded the riverine condition. In this great depression, the river curves from side

to side, now approaching one bank, now the other, but rarely reaching the foot of the highlands, except at a few points in the vicinity of Santarem and Obydos.

Below the mouth of the Xingú, the *varzea* which, with rare interruptions, forms the banks of the river, as well as the innumerable islands (with the exception of the eastern portion of Marajó), is densely wooded, the rubber tree being particularly abundant and characteristic. From the same point to the mouth of the Rio Negro it is frequently open, and covered with coarse grasses and marsh plants. In certain parts, as in front of Santarem and Obydos, it is sufficiently high along the margins of the river and canals, to be above the reach of the ordinary annual floods, and in these parts there are a few plantations of cacáo, and some cattle farms; but for the most part the *varzea* is uninhabited, excepting for a few months during the rubber season, in the wooded portions, and during the dry season, in the region of the open plains, when the herds are driven from the highlands to take advantage of the pasturage. Besides margining the main river, the *varzea* extends innumerable branches into every break in the margin of the highlands, produced by the valleys of the tributaries, whose own flood plains are so closely united to that of the Amazonas, that it is often difficult to determine where the valley proper of a tributary terminates and where that of the Amazonas begins.

The highlands or *terra firma* are very variable in character and elevation, but may be classed in three divisions, viz: low plains, high plains, and irregular or mountainous regions. The first, having only a few feet of elevation above the *varzea*, are slightly developed in the lower Amazonas region, above the mouth of the Xingú; but from that point to the sea, the low plains are of considerable extent and importance, forming the campos of the island of Marajó and a wooded belt on each side of the river, which belt, in the vicinity of Pará, has a considerable extension towards the south. The elevated plains lie on the southern side, at a considerable distance back from the river, behind the low plains just mentioned, in the region about Pará; but to the westward they approach more and more nearly to the river, until finally they appear on its banks, in the bluffs of Cury, a little below Santarem, and afterwards on the same side, in the Serra dos Parintintins, near Villa Bella. On the northern side they form a series of high table-topped hills, which, lying a few miles back from the river, commence almost in front of the mouth of the Xingú, and, under the names of Serras de Almeirim, Parú, Velha Pobre, Parauaquára, etc., extend westward behind Monte Alegre as far as, or beyond, the river Trombetas. The same plains appear also in the lower highlands of Monte Alegre and Obydos.

Where they have not suffered denudation these plains form table-lands, highest on the northern side of the river, where those just mentioned reach an elevation of about 1,000 feet, while those of Santarem and others on the southern side have less than half this elevation. In many regions they have been reduced by denudation to low, gently undulated plains, like those

of Prainha, Monte Alegre, Santarem and Obydos, in the midst of which there appears occasionally a conical or flat-topped peak, to attest the original character of the plain and the extent of the denudation. The table-lands and their slopes are generally wooded, while the lower undulated plains are open and grassy, covered with a barren soil of loose sand. In the interior, on both sides of the river, these table-lands appear to rise gradually in height, until they become united with the more elevated plains of central Guiana and Brazil.

The last division of the highlands, that of the hilly or mountainous country, is represented, near the northern bank of the Amazonas, by an isolated group of mountains, in the vicinity of Monte Alegre and Ereré. These rise abruptly in the midst of a plain to a height of 1,000 feet, and are, in general, rocky or sandy and barren. Associated with these mountains and having the same geological structure is a low, stony campo. Ascending the tributaries on both the northern and the southern side, there is found, in the regions of the rapids, at a distance varying from 50 to 200 miles from the main river, a hilly country, whose highest points are, in general, lower than those of the Ereré group of mountains. These hilly regions are usually well-wooded, with many valuable kinds of timber, the Brazil and sapucaia nut trees (*Bertholletia excelsa* and *Lecythis grandiflora*) being very abundant and characteristic. To these hilly regions succeed, on the north, the high mountains of Guiana and, on the south, the table-lands of central Brazil.

The differences above noted in the different regions of the highlands or *terra firma* depend on the geological structure of the valley, and before describing minutely the different formations, it may be well to present a general sketch of the geology of this part of the valley, and indicate the relations of the regions above described.

Prof. Hartt has well described this structure as follows ;* "The Amazonian valley first appeared as a wide strait between two islands or groups of islands, one now forming the base and nucleus of the Brazilian plateau, the other, on the north, the plateau of Guiana. These islands first appeared at, or shortly after, the beginning of the Silurian Age."

In this canal, before the elevation of the Andes, were deposited a series of beds, representing the Upper Silurian, Devonian, Carboniferous and Cretaceous, which appeared successively in dry land on each side, narrowing the strait between the two islands. Prof. Hartt continues: "Before the rise of the Andes the valley of the Amazonas consisted simply of two gulfs united by a narrow strait. The Andes were thrown up across the mouth of the western gulf, converting it into a basin, though it probably had an outlet both to the north and south. The whole continent was afterwards depressed, so that the waters covered widely the Guayanian and Brazilian plateaux, and the Tertiary beds were deposited there, varying in thickness, coarseness or fineness, according to the conditions under which they were formed. * * * *

* Journal of the American Geographical Society, Vol. III, p. 231, 1872.

"When the continent was once more brought above water, the plateaux, leveled by their new acquisition of strata, first rose; but, by and by, the present water sheds, joining the great plateaux with the Andes, came above water and the Amazonian valley became a Mediterranean, communicating eastward with the Atlantic by a narrow strait. The soft Tertiary beds of the province of Pará were rapidly denuded by the action of the sea during the rise of the land. Probably, while Guiana existed as an island, the Amazonas felt the influence of the equatorial current, which may have aided in carrying away the results of denudation. In the end, the Tertiary beds were completely swept away over an immense tract of country; the Serras of Pará and the similar mountains to the northward were left as monuments of their existence. * * * While the Tertiary sheet was being denuded away, the streams from the highlands were cutting for themselves valleys through the same beds, and these, forming estuaries, were widened to a greater extent than it would have been possible for the streams themselves to have done. During this epoch of denudation deposits were formed, not only in the interior sea, but also in the gulf into which it opened to the east. * * * As the rise continued, the interior sea, now shallowed by much sediment and freshened by the tribute of a thousand streams, was rapidly narrowed in area, and the river Amazonas, properly speaking, which hitherto emptied into a lake at the foot of the Andes, began to extend its channel, following the retreating waters."

The above quotation explains clearly the origin of the *varzea*, of the low plains of Pará, and of the higher plains of the interior of the province. In the hilly regions the inclined beds of the formations older than the Tertiary, including the Cretaceous, the Palæozoic and the Archean, appear in virtue of the denudation of the overlying Tertiary sheet.

The rocks of the ancient islands, the first lands that appeared in the ocean in which the continent was forming, have been profoundly metamorphosed, being converted into granite, gneiss, quartzite and metamorphic schists, and by reason of this, the extent of these islands may be approximately determined by the study of the distribution of the metamorphic rocks. Those of the north appear in the high mountains of Guiana, along the boundary between Brazil and Guiana and, decreasing in elevation towards the south, extend to a line that, beginning near the Atlantic and the mouth of the Amazonas, in about latitude 1° N., extends a little south of west, to the confluence of the Rio Branco and Rio Negro, between latitudes 1° and 2° S. Along this line, which represents the ancient coast, the metamorphic rocks are in general only exposed in the valleys, by the denudation of the Tertiary beds. To the west of the mouth of the Rio Branco they extend to, or beyond, the upper Rio Negro.

On the Brazilian side, the metamorphic rocks only form high mountains in regions far distant from the Amazonas; but they are met with under the other formation in the greater part, if not in all the elevated portions of Brazil. In the Amazonian region, they form the rapids of the rivers Tocantins, Xingú, Tapajos and Madeira, the line of exposures passing the

Tocantins between 3° and 4° of south latitude, the Tapajos between 4° and 5°, and the Madeira between 8° and 9°, at the rapids of São Antonio. The lower Madeira appears to mark approximately the western limit of the ancient metamorphic region, because in the next river to the westward, the Purús, the rocks under consideration were not met with by Chandless, in the course of his careful exploration. The parallelism of the course of the lower Madeira with the great surface features of eastern Brazil, where the metamorphic rocks are thrown into great folds, trending north-easterly, has already been noted. It seems possible that the Madeira is directed by such a fold, or, what is more probable, by a margin of the metamorphic region, which should there have that direction. It is possible that the Guaporé also marks another margin of the same region, which being transverse to the folds is independent of their trend. It is certain that in the Guaporé region there was a canal between the metamorphic region of Brazil and a similar one in Bolivia, the Chiquitos region of D'Orbigny, comparable with the strait between Brazil and Guiana, now occupied by the Amazonas.

As in eastern and central Brazil, the metamorphic rocks of the Amazonian region can be naturally divided into two very distinct series, of which one, the most ancient, consists of crystalline rocks, including gneiss, gneiss-granite and syenite, and the other, more modern, of altered, but in general non-crystalline rocks, consisting of quartzites, metamorphic schists and crystalline limestones. The older series corresponds in character and geological age with that of the Serra do Mar and Serra do Mantiqueira, in the provinces of Rio de Janeiro and Minas Geraes, which was referred by Prof. Hartt to the Laurentian. This series has been but little studied in the Amazonian region. Castelnau speaks of gray gneiss on the Tocantins above the first rapids, and Chandless met with gneiss in a similar position on the Tapajos. Sñr. Ferreira Penna, of Pará, informed me that the rapids of the Xingú are formed by gneiss and diorite, and showed me specimens of the first, consisting of flesh-colored feldspar and quartz with a small proportion of black mica, the rock in hand specimens appearing massive and granitoid. The lower rapids of the Madeira are also formed of gneiss, but I have seen no specimens or descriptions of the rock. On the northern side, gneiss was met with *in situ*, by Sñr. Penna, in the rapids of the Araguay, a small river emptying into the Atlantic, a little to the north of the mouth of the Amazonas, and pebbles of the same rock were met with in the explorations of the Geological Commission, on the rivers Maecurú, Curuá, and Trombetas. I am informed by the engineer, Maj. Coutinho, that gneiss is the prevailing rock on the Rio Branco, except at the mouth, where he found red syenite. I found this last rock also in a zone about half a mile in width, at the second rapid of the river Trombetas, and saw pebbles of the same on the Maecurú, coming from some point above that reached by our explorations. I could not determine, in the short time at my disposal on the Trombetas, whether the rock is stratified or not, and it is possibly of eruptive origin. The syenite consists princi-

pally of flesh-colored feldspar, with a small mixture of hornblende and small scattered spots of a green mineral in decomposition. Quartz is entirely lacking.

The rocks of the second metamorphic series are well exposed in the first rapids of the Tocantins, where they were examined as far as the Cachoeira de Guariba, by Prof. Hartt in 1870. The following notes are taken from his manuscripts. Ascending the Tocantins, the river is at first margined by bluffs of Tertiary sands and clays which, as the rapids are approached, recede from the river and the metamorphic rocks begin to appear. The first exposure of these last met with, is "A granular quartzite, very hard and with a saccharine fracture, the rock being much traversed by quartz veins. The stratification is very obscure and the rock appears to have a sort of slaty structure. In some places it is very compact, bluish and cherty, and is so cut up by veinlets as to appear honey-combed on decomposition. Next appears, at the Ponta do Noberto, a talcose rock, badly decomposed, but appearing to have an easterly dip. Above this is a bed of compact reddish quartzite. From the Praia dos Mortos there extends a long line of similar rocks, with an easterly dip. At Jequirapuá, I found the following section, given in ascending order :

1. Shaly sandstone.
2. Compact white sandstone, rather fine grained, the grain being clear. It weathers brownish, and is traversed by quartz veins.
3. A thin band of purple shale, stratification obscured by faults and oblique slips.
4. Heavy band of ferruginous shale, much decomposed.
5. Bed of very compact bluish, whitish and reddish mottled quartzites.
6. Red shale much traversed by little veins. Just below Alcobaça, I observed quartzite with a north-east dip. At Alcobaça are heavy beds of bluish quartzite, very hard and presenting surfaces polished by the river."

Compact quartzites were observed at various points above Alcobaça, in one place with the strike corresponding with the direction of the river, forming long rocky islands or lines of rock. The dip is well marked, being a few degrees north of east, the angle being about 40°.

"Just below the Cachoeira (rapid) de Tapanhúaquara are green schistose rocks, dipping eastward, and much diorite. In the schists I found amianthus and serpentine. The rocks that choke up the river and form the rapids are, as far as I could determine, a series of gray quartzites, interstratified with thin beds of finely laminated shale. The upper end of the high wooded Ilha das Pacas is composed of a mass of hard, vitreous-looking, bluish or reddish quartzite, much traversed by little quartz veins. On the left bank opposite are ledges and skerries of a slaty rock, with a strong easterly dip. The islets of Janaúquara are bare masses of a hard cherty rock, whose relations to the other rocks I did not determine.

"At Porta de Braga, a bluff projection on the left bank of the river, the shore is encumbered by very large masses of iron ore, in part a mammillary hematite. The rocks of the vicinity, consisting of quartzites and sand-

stones, have a strong easterly dip. As I remember it, the deposit appears to be superficial, and I doubt if it is of economic value.

"Opposite the Praia Grande is a very long narrow line of rocks, running south a few degrees east, and flanked by the schistose rocks, which here present the ordinary eastward dip. The line of rocks is formed by a narrow outcrop of diorite, which I suspect to form a dyke. This diorite is much cracked and, decomposing concentrically, the fragments give rise to a confusion of rounded blocks.

"Near by, the slaty rocks again appear, with the cherty rocks apparently overlying them in discordance of stratification. These latter rocks may therefore be of much later origin. In one place I thought that I observed signs of horizontal stratification. Near the upper end of an enormous sand bank, called Praia Grande, the slaty rocks crop out again, the strike being N. 30° W. and the dip 27° E.

"The Cachoeira de Guariba is formed by the outcrop of a series of metamorphic rocks, an alternation of shales, quartzites and limestones, extending across the river, forming a sort of dam. The strike here is somewhat irregular, but usually a few degrees west of north, the dip being eastward and at a moderate angle. I could not ascend above the Cachoeira de Guariba, from lack of time and of a proper boat. From all that I was able to judge, the metamorphic rocks must extend much further up the river, and it would be very important to have them examined. Whether the whole series that I saw belongs to the same geological horizon or not, I was unable, in the absence of fossils, to determine, but, after my studies of the Carboniferous and Devonian of the Amazonas, I think there can be little doubt that the series is Silurian.

"It is interesting to note the dip of these rocks, which is pretty constantly towards the east, the strike being remarkably northerly. The fact of the occurrence of trap dykes is also important. I saw no porphyries like those of the lower falls of the Tapajos, and I cannot help thinking that the Tocantins beds above described are newer than those of the Tapajos."

The metamorphic rocks of the rapids of the Tapajos were described by Prof. Hartt in the Bulletin of the Cornell University. They consist of quartzites and other rocks similar to quartzites, but without apparent granulation, the beds being traversed by enormous dykes of porphyry and diorite. They are very compact, of a red or chocolate color, frequently marked by little green points, due to some undeterminable mineral in decomposition. In hand specimens the amorphous rocks appear to be igneous, a few scattered crystals of feldspar giving them the appearance of porphyry; but seen in mass, the water-worn surfaces show with great distinctness, lines of lamination and wave and ripple-marks, which prove conclusively the sedimentary origin of the rock. The beds are inclined 15°-20° S. E., the strike being N. 30°-40° E.

The porphyry of the dykes is evidently eruptive. It consists of a compact, amorphous, feldspathic base of a dark chocolate color, in which are scattered crystals of red feldspar, rounded grains of quartz and little

masses of the green mineral above mentioned. There was also observed in the cachoeiras, two exposures of crystalline rocks which appear to form dykes, but this character was not well determined. One of these is fine-grained and dark-colored, the other consists of light-red feldspar, with grains of quartz.

We found on the Trombetas a series very similar to a part of that of the Tapajos. It is exposed in the third cachoeira, called Quebra-potes, and also in the lower course of the river Cachorro, which empties into the Trombetas just above that cachoeira. The rock varies in color, some beds being dark red, others purplish, and like that of the Tapajos it is marked by green spots. The mass is amorphous, feldspathic, sometimes with small grains of glassy quartz, and it may be classified as felsite or eurite. The stratification is very distinct, and the lamination, wave and ripple-marks are as clearly shown as in any modern sandstone. The beds of felsite rest on those of the syenite already described, which is also marked by green spots, and dip 20° N. E., the strike being N. 30° W. Resting unconformably on this series are beds of sandstone, containing Upper Silurian fossils.

This last observation is important, proving as it does that the metamorphism of the rocks and the dislocation of the beds must have taken place during the Lower Silurian or Archean. I am convinced that this conclusion can be extended to the whole metamorphic region. The similarity on lithological characters of the rocks of the Trombetas and those of the Tapajos is such, that it can scarcely be doubted that the formations in the two localities are identical. The difference in strike, from N. N. W. on the Trombetas, to N. N. E. on the Tapajos, can readily be admitted in a single system of upheaval, which can include also the disturbed rocks of the Tocantins, where the strike is N. or N. N. W. It should be observed that, while the compact quartzites of the Tocantins resemble the rocks of the Tapajos and Trombetas, the rest of the Tocantins series, consisting of granular quartzites, talcose schists, and crystalline limestones, recall the rocks of the rivers Araguay, and upper Tocantins, and of the mountains of Goyaz and Minas Geraes.

It has long since been observed that the metamorphic rocks of Brazil, Guiana and Venezuela have in general a north-easterly strike; later observations, however, have shown that the strike is often variable, frequently taking a north westerly direction. It seems probable, therefore, that the epoch of metamorphism and upheaval of the ancient rocks was the same in eastern Brazil and Guiana as in the Amazonian region, that is to say, it was anterior to the Upper Silurian.

The evidence in respect to the epoch of metamorphism and upheaval afforded by other regions of Brazil is very scanty, but, as far as it goes, it sustains this generalization, although it must be confessed it is as yet insufficient to entirely confirm it. In the provinces of Bahia and Sergipe there is a series of beds of undetermined age, but which appears to be either Devonian or Carboniferous. These beds have been disturbed without being metamorphosed, and they rest unconformably

on gneiss, and are overlaid unconformably by Cretaceous deposits. The metamorphism of the gneiss in this region was, therefore, early Palæozoic or Archean. In the southern provinces, the evidence is more conclusive. In Santa Catharina and Rio Grande do Sul, beds, whose Carboniferous age appears to be well proven, lie horizontally above inclined metamorphic beds. These Carboniferous deposits extend across the province of Paraná to the southern part of the province of São Paulo. Near Ponta Grossa in Paraná, Mr. Wagoner, assistant to the Geological Commission, found, underneath the Carboniferous beds, others, also horizontal, containing Devonian fossils. In that region, therefore, we may refer the upheaval and metamorphism to a period anterior to the Devonian, and probably, as on the Amazonas, to one anterior to the Upper Silurian.

We have seen that the metamorphic rocks present two distinct series, of which one, consisting of crystalline rocks, was, with all probability, referred by Prof. Hartt to the Laurentian. It is probable that this series had been metamorphosed and disturbed before the deposition of the second non-crystalline series. It is true that there appears to be a concordance in stratification between the two series, but it is by no means certain that this concordance is perfect, and that the older series had not been disturbed (probably in the same general direction), before the great general movement of upheaval, which affected and gave character to the whole metamorphic region of Brazil, if not of the entire continent.

In regard to the age of the second metamorphic series, we have by elimination reduced it to the ages intermediate between the Laurentian and the Upper Silurian, that is to say, the Huronian and the Lower Silurian. It seems probable that both are represented, and, accepting Prof. Hartt's supposition, that the rocks of the Tapajos are more ancient than those of the Tocantins, we may provisionally refer those, with the felsites of the Trombetas, to the Huronian, and these to the Lower Silurian, a reference which accords with another opinion of Prof. Hartt, that is, that the granular quartzites (itacolumites) and talcose schists of Minas Geraes belong to the Lower Silurian.

At the end of this movement of upheaval and folding, the primitive islands of Brazil and Guiana had received enormous additions to their original areas, and extended to the limits already indicated, in treating of the distribution of the metamorphic rocks, leaving between the two islands a strait, some three or four degrees of latitude in width, in the narrowest part. From that time, which was during, or at the end of, the Lower Silurian commenced the proper history of the Amazonian valley.

In this strait was deposited, without great oscillations of level or upheavals, comparable with those that had disturbed the metamorphic series, a series of beds gently inclined from the margins towards the center, representing the formations from the Upper Silurian to the Cretaceous, inclusive. There were, however, before the deposition of the Tertiary beds, considerable eruptions of trap and diorite, and local disturbances in at least one region, that of Ereré. This region is so important in the study of the geology of the Amazonas, as to merit special description.

Situated on the margin of the *varzea*, and about two leagues to the westward of the village of Monte Alegre, there is an isolated group of mountains, consisting of numerous, small monoclinal ridges, separated one from another, and disposed in an ellipse around a central plain, of which the elevation is a few feet at most above the level of the Amazonas. The major axis of the ellipse is some ten or twelve miles long, and lies in the direction of E.-W. The principal mountain, called Serra de Tajurí, is about 350 metres high, and is situated on the north-east side of the ellipse; from Tajurí, a curved line of low ridges extends to the second serra in size, that of Ereré, which is on the southern side, and has an elevation of 250 metres; then come the smaller serras of Aroxí, Maxirá, Paraizo, Julião and Urucury, the last being placed at the western end of the ellipse; between this and Tajurí there is a considerable number of low serras, without names, which have never been explored. All of these serras present an abrupt slope towards the central plain, and a gentle slope, following the inclination of the strata, on the opposite side. This inclination, which varies from 10° to 20° , is N. N. E. in Tajurí, E. in the ridges between Tajurí and Ereré, S. in this last, and W. in Urucury. This variation in dip proves that this group of mountains is only the remnant of a great anticlinal, of which the central, and by far the larger, part has been denuded away. This opinion, respecting the structure of the region, is supported by the structure of the low Serra de Paitúna, which is situated outside of the ellipse, some three or four miles to the south of the Serra de Ereré, with which it is parallel. As was to be expected from its position in relation to the other mountains, Paitúna was found to be a synclinal ridge. It is possible that to the northward of Tajurí there are other synclinal ridges, similar to Paitúna.

There have not yet been definitely recognized in other parts of the valley, any elevations, corresponding in age and structure to those of Ereré. I have reasons, however, for believing that, in the vicinity of Obydos, the Serra de Curumú and perhaps that of Cunury may belong to the same system. Near the margin of the metamorphic region, on the Guiana side at least, the Palæozoic beds are gently inclined, at an angle of 5° - 10° ; but in general these beds appear to lie horizontally.

The first member of this Palæozoic series of the Amazonas is the Upper Silurian. The rocks of this age appear on the Guiana side, in a belt of a few miles in width, which extends in the direction east-west for a considerable distance, if not along the whole southern margin of the metamorphic region of Guiana. They have been recognized on the Trombetas, Curuá and Maecurú, and from specimens brought by Sr. Ferreira Penna, from the Maracá, a small river which empties nearly opposite the western end of Marajó, I judge that they extend eastward nearly to the Atlantic.

These rocks have been best studied on the Trombetas. They there appear in a belt four or five miles wide, forming the first and part of the second cachoeira. They were also found, well exposed, in a hill of some 100 metres of elevation, called Oiteiro do Cachorro, situated on the right bank of the river of the same name, a little above its confluence with the Trom-

betas. The lower part of this hill is composed of felsite, above which the Upper Silurian beds form a magnificent overhanging cliff. In the lower part of the second cachoeira, called Vira-Mundo, the Silurian beds rest on syenite. The dip is approximately 5° S. S. W., the strike being N. 65° W. I estimate the total thickness of the series at about 1,000 feet.

The character of the beds is remarkably uniform. They consist almost exclusively of hard argillaceous and micaceous sandstones, generally thin-bedded, but with some massive beds of pure sandstone. The color is very variable, being white, yellow, red or purplish, but the predominant color is some shade of red, generally mottled or banded. Limestones are entirely lacking, and schists are rare and of slight importance, as regards their thickness, but interesting on account of their peculiar characters. One set of beds of cherty schist, about 20 feet thick, is found at the base of the series, in contact with the syenite. This rock looks like one that had suffered some alteration, and this appearance might be taken to prove that the syenite is of igneous origin, and that it had been ejected after the deposition of these beds, effecting an alteration in them. As, however, the altered appearance is less marked in the part of the schists which is in immediate contact with the syenite, than in the upper portion of the bed, I believe that their peculiar appearance is due to some other cause. Another schist of undetermined thickness occurs at the base of the cliff, forming the front of the Oiteiro do Cachorro. It consists of a soft clay, impregnated with alum, which also occurs abundantly in free crystals.

At the foot of the Cachoeira Vira-Mundo, and just above the cherty rocks above mentioned, there is a bed of fine-grained, yellowish sandstone, containing a few fossils of which we collected with considerable difficulty sufficient to determine the age of the formation. The fossils are all in the state of casts and, except a species of *Beyrichia* and a fragment of a Trilobite, are all Molluscan. The most common is an *Orthoceras*, which is however indeterminable. The genera, *Rhynchonella*, *Orthis*, *Chonetes*, *Strophodonta*, *Lingula*, *Pholidops*, *Bucania*, *Conularia* and *Otenodonta* are represented. Among these the species *Orthis hybrida* Sow., *Lingula cuneata* Conrad, and *Bucania trilobata* Conrad are recognizable. In the Oiteiro do Cachorro are thin beds of shaly sandstone, with well marked fucoids, apparently of the species *Orthrophychus Harlani* Conrad. These fossils indicate a close correspondence with the Medina sandstone of the Niagara group. Throughout the whole series worm-tubes are abundant.

The same series of beds were met with on the Curuá and Maecurú, with characters identical with those just described for the Trombetas. On these rivers the Silurian rocks form cachoeiras, that were impassible with the means at our disposal, and for this reason we did not succeed in reaching the base of the series, where the fossiliferous beds occur. Worm-tubes and indeterminable fucoids were, however, met with. The Upper Silurian has not yet been recognized on the southern side of the valley, but, as all the sections on that side are very incomplete, it is by no means certain that they do not exist. It is possible that the cherty beds of the Tocantins,

mentioned by Prof. Hartt, may belong to this series ; but as cherts are common also in the Devonian and Carboniferous, it is impossible, in the absence of specimens, to form a definite opinion respecting the age of those of the Tocantins.

The Devonian is best exposed on the northern side of the valley, where it forms a broad belt, bordering the narrower Silurian belt, and disappears under the Carboniferous deposits, to reappear farther south in the Ereré anticlinal. The beds of this age are variable in character, and may be divided by differences in the rocks and fossils into three groups, which, for convenience, may be named for the locality in which each was best studied, the Maecurú, the Ereré and the Curuá group. It must be remembered, however, that all three of these groups are represented at each of the above localities.

The first, or Maecurú group, consists of a few beds of coarse, white or yellowish sandstone, which, on the Maecurú and Curuá, have a thickness of thirty feet. On both of these rivers this group is well exposed, with a dip of about 5° S. S. W. The rock is hard in some layers, but very friable in others, and is highly fossiliferous. On the Trombetas it is represented by a bed of sandstone, so friable as to be almost a bank of sand, and at Ereré only a portion of the upper bed is exposed, and no fossils were found at either of these localities. The fossils are impressions, colored and somewhat consolidated by oxide of iron ; they are beautifully preserved, and so abundant and varied that, with a few hours' work, we made an enormous collection, containing about seventy-five species. Trilobites are represented by species of *Homalonotus*, *Dalmania*, *Phacops* and *Prætus* ; Gasteropods by *Bellerophon*, *Holopea* and *Platyceras* ; Lamellibranchs by a large number of species of the genera *Modiomorpha*, *Limoptera*, *Edmondia*, *Grammysia* and others. The most interesting fossils are, however, the Brachiopods, which have been carefully studied by Mr. Rathbun, who has described* twenty-one species from the Maecurú, of which thirteen were also found on the Curuá in equivalent beds, nine in the overlying beds of the Ereré group, and six in the lower and middle Devonian of New York. Of the species common to this group and that of Ereré, those that are abundant in one are generally rare in the other, and this, with the numerous species which are limited to each group, gives a special expression to the fauna of each, which justified their separation. The most abundant and characteristic Brachiopods of the Maecurú group are *Amphigenia elongata* Hall, *Spirifera duodenaria* (?) Hall, *Strophodonta perplana* Hall, *Rhynchonella dotis* (?) Hall, *Vitulina pustulosa* Hall, *Streptorhynchus Agassizii* Hartt, and new species of *Chonetes* and *Orthis*. The two first and the last new species were not met with at Ereré. It will be seen that these fossils indicate a close relationship to the Corniferous group, which bears about the same stratigraphical and palæontological relation to the overlying Hamilton group, as does the Maecurú group to that of Ereré. These last two may, therefore, be considered as the Brazilian equivalents of the North American formations.

* Proceedings of the Boston Society of Natural History, Vol. XX, pp. 14-39, 1878.

The Ereré group occupies a considerable area in the central plain between the mountains of Ereré, but so sub-divided, denuded and disturbed by eruptions of trap, as to present serious difficulties for study, which were, however, overcome by Mr. Smith in 1876, who succeeded in making a complete section and in proving, by means of fossils, the unity of the group. Mr. Smith calculated the total thickness at about 200 feet, divided between thirteen distinct beds, of which the greater part consist of fine-grained, micaceous sandstone, disposed in thin beds, with subordinate beds of black shale. The sandstone is generally white or yellowish, but exposed to the weather, it becomes reddish, and the shale often weathers white. Near the base of the group there are a few beds of a compact cherty sandstone, that breaks with great regularity into cubical blocks. Fossils are more or less abundant in all of the beds, those of the shale being different from those of the sandstone. The same beds were met with on the Maecurú and Curuá, but less sub-divided, with fewer fossils, and without the shales. The thickness of the group on the Curuá appears to be less than at Ereré. The fauna is very similar to that described from the Maecurú group, but, except in the class of Brachiopods, it is less rich, both in species and individuals. Mr. Rathbun has described twenty-four species of Brachiopods,* two of Trilobites, eight of Lamellibranchs and six of Gasteropods.† Of the first some have already been mentioned; thirteen are limited to this group, of which the most abundant and characteristic are *Retzia Jamesianu* Hartt,‡ *Retzia Wardiana* Hartt, and *Discina lodensis* Hall. *Spirifera Pedroana* Hartt, although it appears rarely in the Maecurú group, is, by its abundance, one of the most characteristic fossils of the Ereré group.

The third or Curuá group consists almost exclusively of black and red shales, passing at times into shaly sandstone. These beds form low cliffs along the rivers Maecurú and Curuá for a considerable distance, lying almost horizontal, except where disturbed by eruptions of diorite. On the Trombetas the black shale forms two short cliffs on the river bank, and the red shale is badly exposed on a lake near by. At Ereré these rocks are exposed in the eastern part of the plain, and in the base of the serras, particularly that of Tajurí, the front of which is composed almost entirely of these shales. The black shale forms the lowest bed, the thickness of which, on the Curuá, is estimated by Mr. Smith at 300 feet. It is well laminated, almost slaty in structure, and in the lower part contains numerous large, calcareous and arenaceous concretions. The first are bluish black in color, have well developed cone-in-cone structure and emit, when struck with a hammer, a strong odor of petroleum.

The reddish shale lies above the black, having more or less the same thickness. It is generally chocolate-colored, mottled with spots of a darker hue and banded, parallel with the stratification, with white, yellow or

* Bulletin of the Buffalo Society of Natural Science, Vol. I, No. 4, 1874.

† Annals of the Lyceum of Natural History of New York, Vol. XI, May, 1875.

‡ It is but just to mention that the gentleman, to whom this species is dedicated, has more than any other, not specially devoted to science, contributed to the progress of geology, not to say of science in general, in Brazil.

black. The rock consists of clay, mixed with a considerable proportion of finely-divided mica and sand, the last often forming independent layers, a few inches thick. The only fossils found in these shales were Fucoids, of the genus *Spirophyton*, and small fruit-like bodies, resembling very much a flattened currant, consisting apparently of a thin pellicle enclosing two to six small grains. The *Spirophytons* are apparently identical with those described by Prof. Hall, from the Hamilton group of New York. They occur abundantly in all the localities, in both the black and red shale, near the junction of the two.

On the Curuá and Maecurú the red shale, which is undoubtedly Devonian, is followed by beds of coarse sandstone which, according to Mr. Smith, are at least fifty feet thick on the Curuá. This is followed by fossiliferous Carboniferous beds. The red shale is also overlaid by coarse sandstone, in the mountains of Ereré, but it is not certain that this sandstone is of the same formation as that of the Curuá.

As regards the extension of the Devonian series, it has been recognized as far west as the river Uatumá, a small river between the Trombetas and the Rio Negro. On the southern side of the valley, there are, on the Tapajos, shales containing *Spirophyton* and calcareous concretions, which were referred provisionally to the Carboniferous by Prof. Hartt, but which seem to me to be Devonian, and I refer to the same age the black shale found by Sñr. Penna on the Xingú.

Of all the Palæozoic deposits of the Amazonas, those of the Carboniferous occupy the most extensive area and, at the same time, present the greatest difficulties to study. Composed for the most part of soft beds, they suffered extensive denudation, during the interval between the close of the Carboniferous and the beginning of the Tertiary, during which time they were, for the most part, exposed above the level of the sea; by the deposit of the great Tertiary series they were concealed, over immense areas, and where they have been again exposed by the denudation of the Tertiary, they have again suffered destructive denudation. At present, the exposures are poor and unsatisfactory, rendering very difficult the determination of the relations of the different beds and the vertical extension of the series. Mr. Smith, who has best studied these deposits, is of the opinion that their total thickness is not less than 2,000 feet, and, although the data for this calculation is very defective, I cannot say that it is exaggerated.

The horizontal extension is more easy to determine. On the Tapajos the rocks of this series appear at intervals, from a point just below the rapids to near the village of Aveiros, a distance of about eighty miles. It is possible that they extend still farther north to near the mouth of the Tapajos, since I am credibly informed that, near Santarem, a bed of limestone occurs, which is most probably of Carboniferous age. To the westward of the Tapajos, they have been recognized by Chandless on the Mauhé-assú, a small river between the Tapajos and Madeira, and I consider it probable that they extend as far west as the latter river. I have information that leads me to believe that they exist to the eastward, on the Xingú, and I

think it probable that they will yet be found on the Tocantins. On the opposite or northern side of the valley, they occur close to the margin of the river, in the vicinity of Alenguer, in front of Santarem, and extend for a considerable distance towards the north, along the rivers Curuá, Maecurú and Trombetas; to the west, they extend at least as far as the Uatumá, already mentioned, and to the east, as far at least as the Jauiary, near the village of Prainha.*

The rocks consist of soft shales and sandstone, and of limestone, which last, although of but slight thickness, is the most important, because, having resisted denudation better than the other rocks and being highly fossiliferous, it forms an admirable base of reference in the study of the Carboniferous series. The best exposures of the limestone are on the Tapajos, both above and below the village of Itaitúba, where it is quarried to burn for lime. The thickness is about twenty-five feet, some of the beds being of very pure limestone, of a blue or light brown color, others being darker and somewhat argillaceous and silicious. The fossils being silicified, and consequently more durable than the rock in which they are enclosed, become detached by the slow dissolution of the limestone, and often appear loose, as on the beach in front of Itaitúba. Cherty masses are common in the limestone, and aside from these, two other kinds of chert occur in loose masses which, in the opinion of Mr. Smith, come from some unknown beds above the limestone. One of these kinds decomposes to a white, chalky mass, the other, which forms large, rounded boulders in front of Itaitúba, takes on, in decomposition, the appearance of a porous sandstone. Cherts of various kinds are very abundant in the whole Carboniferous region, and are often highly fossiliferous, but the beds from which they originate are as yet unknown.

Above the limestone at Itaitúba, there are beds of soft, brown sandstone and of shale, of unknown extension, and below there is a heavy series of green, red and black shales, some of which contain *Spirophyton* and are most probably Devonian. Of the Carboniferous rocks of the Mauhé-assú, the only notices we have are of the limestone, which is identical in character and fossils with that of the Tapajos. Passing now to the northern side, we find a thick bed of limestone at the foot of the Serra of Tajuri, in the Ereré region, where it is associated with a yellowish mottled sandstone, much appreciated by the people for whetstones. The exposure, however, in this locality is so unsatisfactory, that it was impossible to determine its relation to the other beds of the serra. In the region between the Maecurú and Curuá, there are exposed, over an extensive area, a variety of beds, which Mr. Smith attempted to arrange in a section which, although somewhat defective, is of considerable interest.

*In this sketch of the character and extension of the Amazonian Carboniferous, I have, aside from the observations of Prof. Hartt and myself, drawn largely from the excellent studies of Mr. Smith on the northern side of the Amazonas, and am also indebted to Mr. Coutinho, the first discoverer of Amazonian fossils, and to Messrs. Chandless, Brown and Rodrigues, for notices of its existence in regions, not visited by the members of the Geological Commission.

On the Curuá, Mr. Smith found, above the beds of undoubted Devonian age, a small series of unfossiliferous sandstones, and then at Praia Grande, loose silicified fossils, identical with those of Itaitúba, which indicate the presence of a bed of limestone. Above this there is a series, the estimated thickness of which is 600 feet, composed of alternations of soft sandstones and sandy shales, of which certain layers near the upper part, exposed at a place called Pacoval, are highly fossiliferous. At lake Cujubim, near the river Maecurú, the section begins below with massive beds of yellow sandstone of undetermined thickness; then comes two feet of hard sandstone, followed by a bed five feet thick, of impure, silicious, fossiliferous limestone, which is separated by ten feet of sandstone and shale from a bed of equal thickness of pure limestone, containing fossils identical with those of Itaitúba; above this are soft beds of sandstone and shale, with fossils identical with those of Pacoval on the Curuá. In various other localities in the vicinity of Alenguer, Mr. Smith found exposures of sandstone and shale of very varied characters, which appear to belong above the series at Cujubim, and to represent, in part at least, the upper portion of the Curuá section. Mr. Smith well observes that the variation in the character of these Carboniferous beds, in both their horizontal and vertical extension, indicates deposition in shallow water, during subsidence. The limestone appears to be always near the base of the series.

The exposures of Carboniferous rocks on the Trombetas are so unsatisfactory, that they scarcely do more than prove the existence there of sandstones, shales and limestones, with fossils identical with those of the other localities.

The Carboniferous fauna of the Amazonas is very rich, containing more than a hundred species of Brachiopods, Lamellibranchs, Gasteropods, Corals, Bryozoans, Echinoderms, Fishes and Trilobites. Of these, I have already published descriptions of the Brachiopods of the Tapajos,* and hope soon to give descriptions of the remainder. The fauna shows the closest relationship to that of the Coal Measures of the Western States, more than half of the species being identical. I have already shown that the Bolivian and Peruvian Carboniferous faunas, as far as they are known, are equivalent to the Brazilian, and to that of the North American Coal Measures.

The following are some of the most important species common to the three regions: *Spirifera camerata* Morton (*S. Condor* D'Orb.), *Athyris subtilita* Hall, *Retzia Mormonii* Marcou (*R. punctulifera* Shumard), *Productus Cora* D'Orb., *Productus semireticulatus* Martin, and *Chonetes glabra* Geinitz. The following are, among others, in addition to the above, common to Brazil and the United States: *Spirifera rockymontana* Marcou, *Spirifera planoconvexa* Shumard, *Spirifera perplexa* McChesney, *Myalina kansasensis* Shumard, *Allorisma subcuneata* Meek and Hayden, *Aviculopecten occidentalis* Shumard, *Aviculopecten carbonaria* Stevens, *Schizodus Wheeleri* Swallow, *Lima retifera* Shumard, *Entolium aviculatum* Swallow, *Bellerophon carbonarius* Cox, *Rhombipora lepidodendroides* Meek, and *Synocladia biserialis* Swallow.

* Bulletin of the Cornell University (Science), Vol. I, No. 2, 1874.

No satisfactory sub-division of the Carboniferous beds of the Amazonas can as yet be made. The fossiliferous beds at the different localities appear to belong to the same limited horizon, and to present always the same fossils. It is true that Mr. Smith found at Curumú and Curucaca, near Alenguer, fossils having a different aspect from those from the other localities, but they are so poorly preserved as to be unrecognizable. The fossils of the calcareous beds are mostly Brachiopods and Corals, while Lamelli-branches are most abundant in the shales and sandstones; but there are many species in common, and the beds are so closely related stratigraphically, that I am inclined to consider the differences in their fossils as due to differences in the nature of the sediments, rather than to a difference in horizon.

While the Palæozoic deposits were being laid down in the Amazonian region, it is to be supposed that the other margins of the ancient Archean and Silurian islands received their quota of deposits and, in fact, in the southern part of Brazil, in the regions now constituting the provinces of Rio Grande do Sul, Santa Catharina, Paraná and the southern part of São Paulo, extensive Carboniferous and Devonian beds were laid down. It is stated also that Carboniferous deposits are to be found in the provinces of Maranhão and Matto-Grosso, on the Guaporé and Upper Paraguay; but, although this seems extremely probable, the fact is not as yet well verified. In the Andean region enormous deposits were formed, during the whole of the Palæozoic. The best known of these are the Carboniferous beds, which appear in the central part of the Cordilheiras, at lake Titicaca, and in the province of Arque in Bolivia; and on the eastern slope of the Andes, at Cochabamba and Santa Cruz de la Sierra, in Bolivia, and on the upper Pachetea, in Peru.

The beds referred to the Cretaceous, have only been recognized with certainty in the mountains of Ereré. We have seen that the Curuá shales of the Devonian series, form in general the base of these mountains. In one place, near the base of Tajurí, these shales are followed by Carboniferous limestones, but in general the Carboniferous beds are lacking throughout the Ereré region, and the Devonian shales are followed by heavy beds of coarse, hard sandstone. In a section made in a hill between Tajurí and Ereré, there are three distinct beds of coarse massive sandstone, separated by beds of micaceous sandy shales, the whole series having a thickness of about 300 feet. Of these three beds of sandstone, the upper or middle, or the two united, form the principal mass of the Serras of Ereré and Paitúna. In the first of these serras were found, in 1871, fragments of fossilized wood, which were referred by Dr. Dawson to the dycotyledonous group of plants, and in the last voyage we found, in Paitúna, a thin bed of argillaceous sandstone, intercalated in the coarser beds of the serra, which was crowded with fossil leaves, belonging to various genera of the same group of plants.

The leaves and woody structure of tropical plants have been too little studied to permit of the specific, and perhaps the generic, determination of these plants. They are, however, of the utmost importance in the

determination of the age of the formation, which can hardly be older than the Cretaceous, and since these fossils are in disturbed beds, which are overlaid by the horizontal deposits referred to the Tertiary, we cannot well consider them as more modern than the Cretaceous.

Fossil leaves, very similar in appearance to those of the Serra de Paitúna, have been found at Tonantins on the Solimões, at Uatapucará on the Tapajos, and at Prainha on the Lower Amazonas, in beds that appear to be Tertiary or recent. A critical examination is required to prove whether or not these fossils from the different localities are identical, or belong to the same horizon. For the present it seems to me most probable that they are distinct, those of Paitúna being the most ancient. It is worthy of note that the fossil leaves at Prainha are in beds of clay and conglomerate that are slightly inclined, and it is possible that, notwithstanding their modern appearance, they may prove to belong to the Cretaceous.

These fossils being in the upper bed of sandstone, the age of the lower beds and of the intermediate sandy shales, between the limits of Upper Devonian and Cretaceous, is undetermined. They are, however, so similar in lithological character, to the fossil leaf beds, that I refer them provisionally to the Cretaceous. What is well proven is, that the elevation of the anticlinal of Ereré took place during, or after, the Cretaceous age. In this connection I may add, that the beds of the numerous Cretaceous basins along the eastern coast of Brazil are always more or less disturbed and inclined.

Near the mouth of the Trombetas we found inclined beds of sandstone, containing pebbles of shale which appear to me to have come from the Devonian or Carboniferous beds, which occur farther up on the same river. In the same region there is a high serra, called Curumú, composed of hard sandstone, the beds of which appear, as seen from a distance, to be inclined, and I suspect that in that region will be found the equivalents of the Ereré Cretaceous beds.

To the south of the mouth of the Amazonas, between Salinas and Bragança, Sñr. Penna has lately discovered fossiliferous limestone, similar to that of the Cretaceous basins of Pernambuco and Sergipe. In the Solimões region there is also, according to Chandless and Coutinho, an extensive Cretaceous area, on the river Purús, characterized by the remains of *Mosasauros* and turtles.

The disturbances which all the formations thus far described have suffered, were accompanied by eruptions of igneous rocks. In the metamorphic region, the syenite and perhaps a part of the granite may belong to this category, a question that can only be solved by further study. In the same region, and also throughout the Palæozoic region, diorite is very common, forming immense dykes, and sometimes apparently forming sheets between the strata of sedimentary rocks. Another igneous rock of doubtful character, which I have referred to as trap, forms numerous narrow dykes in the Ereré and Alenguê region, traversing both the Palæozoic and the Cretaceous beds. The surface is always decomposed, presenting a

scoriaceous appearance, and enclosing crystals of quartz and fragments of the adjacent sedimentary rocks, these last being often so slightly metamorphosed, as to still preserve traces of fossils. The beds traversed by the dykes are somewhat altered, for a distance of a few feet from the point of contact.

The Tertiary beds have been so often mentioned in the course of this article, that little remains to be said regarding their character and distribution. They are distinguished from those of the older formations by their horizontal position, and by the absence of fossils and of eruptive rocks. They consist of sandstones and clays, of brilliant and varied colors, such as white, red, yellow and blue, combined in different shades, so as to produce a very striking effect in the cliffs, which are very frequent along the tributaries, but rare along the main river. The rock is in general very slightly consolidated, except an occasional bed or patch, in which a cement of oxide of iron has produced the coarse ferruginous sandstone, found scattered over the surface throughout the whole of the Amazonian highlands.

The Tertiary series is best presented in the serras known under the collective name of Serras de Parú, which are seen from the river, from Almeirim to near Prainha. These are mountains of circumdenudation, perfectly level on top, and of an elevation of about 1,000 feet. The one nearest to Prainha, called Parauáquára, was visited by Prof Hartt in 1871, who found the structure well presented in the steep, bare front of the mountain. The beds, whose thickness corresponds approximately to the height of the mountain, consist of sandstones and clays, of various colors, disposed in nine distinct divisions. From Parauáquára westward, the series of table-topped hills extend for a long distance, but, lying farther back from the river, they cannot be seen, except from some high point as, for example, the mountains of Eréré. From the Maecurú, I saw a rounded peak, rising above the general level, apparently an island of some older formation, in a sea of Tertiary sandstone. In the vicinity of Monte Alegre there are deposits identical in character with those of Parauáquára, which were evidently laid down after the elevation of the Eréré anticlinal. These deposits, like those of Alenguer and Obydos, have suffered a destructive denudation, which has considerably reduced their original height, which probably was never equal to that of the Serras of Parú.

The Tertiary beds of the southern side of the valley, are, in the Santarem region, considerably lower than those of the north, the difference being probably due to the inclination of the bottom of the Tertiary sea, and the smaller quantity of sediment received by the regions farthest removed from the margin of that sea. The highlands behind Santarem are 400 feet high, and do not appear to have suffered denudation that has diminished sensibly their original height. In a bed of blue clay, exposed on the slope of these highlands, I found worm tubes, the only fossils that the Tertiary beds of this region have yet afforded.

This lack of fossils is noticeable, not only in the Lower Amazonian region, but throughout Brazil. In every province there are beds similar in charac-

ter and position to those just described, but so far they have yielded no fossils, that will serve for their classification, and they have been referred to the Tertiary solely on account of their stratigraphical position. The only Tertiary fossils known from this region are the fossil leaves of *Tonantius*, and the fresh and brackish water mollusks of Pebas and other localities in Perú. These, however, occur in lignitiferous beds, quite different from those now under consideration, and the relation between the two has never so far as I am aware, been satisfactorily determined. The only division that can at present be made in the region of the Lower Amazonas, is between the beds of the high table-lands, and those of the lower plains about Pará and eastern Marajó. These last, consisting of abrupt alternations of coarse and fine sandstone, generally ferruginous, along with colored clays, are certainly more modern than the former, and belong to the later Tertiary or the Quarternary.

During the deposition of the Tertiary, there were considerable movements of depression and subsequently of elevation, but these movements were, as far as is known at present, unaccompanied by disturbances of the strata or eruptions of igneous rocks.

After the elevation of the Tertiary table-lands, began the alluvial deposits of the *varzea*. They consist, according to circumstances and localities, of sands or clays, or a mixture of the two, a yellowish structureless clay predominating, often having above it a bed of black clay, impregnated with vegetable matter. Part of this deposit was without doubt formed in an estuary, while the river was taking possession of the bed prepared for it; but it is now impossible to distinguish the estuary deposits from those that are purely fluvial. The proofs of the estuary condition are not so much in the characters of the deposits, as in the form of the tributary valleys, which are widened in a manner that can only be explained by the action of the tides.

With the formation of the *varzea*, the geological evolution of the valley of the Amazonas terminated. We cannot in this place enter into a consideration of the interesting phenomena, illustrative of Geology and Physical Geography, of which the *varzea* is the theatre. To witness, close at hand, the operation of many of the processes of which these sciences treat, and which have given form and character to the surface of our planet, I know of no region equal to the Amazonas. Between the water and the land, the river and the *varzea*, there is a constant conflict. Islands are formed and destroyed, or floated bodily down stream, by the continual process of destruction at one end, and of formation at the other; lakes, *furos* and *paraná-merins* are being formed, to be again filled up; tributaries extend themselves into the territory proper to the main river, or this throws out one of its lateral channels, to appropriate to itself a part of the valley of a tributary. The conflict, however, is unequal; the force of the river, irresistible as it is in its great floods, is spasmodic in its action, and can be met by a weaker, more constant one, such as is afforded in aid of the growth of the land, by the vegetative force.

Rank behind rank, the various aquatic and marsh plants advance into every shallow, building it up to the common level over which the floods pass, adding new sediment, instead of carrying away that already accumulated. In this way the land is slowly extending itself, confining the river more and more to its proper channel ; but this process cannot materially alter the character of the valley, unless aided by some convulsion of nature.

Much yet remains to be done on the Lower Amazonas, in filling in the details of this imperfect sketch, which will, I trust, be found to be accurate in the main, and which will serve to show how interesting the region is in itself, and in its relation to the rest of the Continent. Of the Upper Amazonas or Marañon region, enough is already known to show its surpassing interest and importance. Between the two, the middle or Solimões region, is an almost perfect blank, in which future explorers will meet with difficulties, even surpassing those presented by the other regions, but will, by well directed efforts, reap results commensurate with the hardihood of the undertaking.

Stated Meeting, January 17, 1879.

Present, 11 members.

Vice-President, Mr. FRALEY, in the Chair.

A letter of acknowledgment was received from the Natural History Society, Emden (100; List).

Letters of envoy were received from the French Minister of Public Instruction; and the Meteorological Office, London, December, 1878.

A letter of thanks for correspondence was received from the Rev. Stephen D. Peet.

A letter respecting exchanges was received from Mr. G. W. Ranck, Curator of the Kentucky Historical Society.

Donations for the Library were received from the Adelaide Observatory; M. P. Volpicelli at Rome; the Geographical Society and *Revue Politique* at Paris; the Meteorological Office, and *Register*, and *London Nature*; the Boston Natural History Society; *American Journal of Arts and Sciences*; *Library Journal* in New York; the Franklin Institute, *College of Pharmacy*, *Journal of the Medical Sciences*, and *Medical News* in Philadelphia; the *American Journal*